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SK Mishra

North-Eastern Hill University, Shillong (India)

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# Construction of Pena's DP2-Based Ordinal Synthetic Indicator When Partial Indicators are Rank Scores

SK Mishra  
Dept. of Economics  
North-Eastern Hill University  
Shillong, Meghalaya (India)  
Contact: [mishrasknehu@yahoo.com](mailto:mishrasknehu@yahoo.com)

**I. Introduction:** A synthetic indicator (or composite index),  $Z[n]$ , is oftentimes a linear combination of  $m$  partial indicators (or the constituent variables of  $Z$ ),  $X[n, m]$ , such that  $Z = Xw$ , where  $w[m]$  is the weight vector. In many cases,  $w$  is extraneously determined (e.g. on the basis of expert opinion), but applications abound when  $w$  is determined intrinsically from  $X$  itself. Factor Analysis or Principal Component Analysis is one of the most popular methods of obtaining  $Z$  (which is called the factor scores). However it has been found that the factor scores thus obtained are highly elitist; often ignoring the poorly correlated partial indicators (OECD, 2003; Munda & Nardo, 2005; Somarriba & Pena, 2009; Mishra, 2011).

In response to the limitations of the Principal Component (or Factor) Analysis as a tool to construct the synthetic indicators, a new method based on Pena's DP2 distance (Pena, 1977) was devised (Zarzosa, 1996; Somarriba & Pena, 2009). Pena's DP2 is defined as:

$$DP2_i = \sum_{j=1}^m \left[ (\partial_{ij}) (1 - R_{j,j-1,\dots,1}^2) \right] = \sum_{j=1}^m \partial_{ij} w_j; \quad i = 1, 2, \dots, n \quad \dots \quad (1)$$

where:  $i = 1, 2, \dots, n$  are cases (e.g. countries, districts, institutions, individuals, items and so on);  $m$  is the number of constituent variables (partial indicators),  $X$ , such that  $x_{ij} \in X; i = 1, 2, \dots, n; j = 1, 2, \dots, m$ ;  $d_{ij} = |x_{ij} - x_{\kappa j}|; i = 1, 2, \dots, n; j = 1, 2, \dots, m$ ;  $\kappa$  is the reference case pertaining to  $\min_i (x_{ij})$ ;  $\partial_{ij} = d_{ij} / \sigma_j$ ;  $\sigma_j$  is the standard deviation of variable  $j$ ;  $R_{j,j-1,\dots,1}^2$ ;  $j > 1$  is the coefficient of determination in the regression of  $x_j$  on  $x_{j-1}, x_{j-2}, \dots, x_1$ .

Moreover,  $R_1^2 = 0$ . It may be noted that the first variable obtains an absolute weight of unity:  $(1 - R_1^2) = 1$  for  $R_1^2 = 0$ . The subsequent variable  $j = 2$  obtains a weight  $(1 - R_{2,1}^2)$  and in general, the  $j^{th}$  variable obtains a weight of  $(1 - R_{j,j-1,\dots,1}^2)$ . Thus, the DP2 method of constructing synthetic indicator differs from the more conventional methods regarding the manner it assigns weight to the constituent variables. For example, the Principal Component Analysis determines the weights ( $w$ ) in  $Z = Xw$  such that  $\sum_{j=1}^m [r(Z, x_j)]^2$  is maximized. For the DP2 method, there is no such clearly defined objective function to optimize. It is also obvious that the weights assigned to a variable will depend on its position in the order (Montero, 2010), which makes DP2-based composite (synthetic) indices indeterminate and arbitrary unless some criterion is used for the entry of variables in the formula or some objective function is set to be optimized.

There could be several procedures to resolve the indeterminacy pointed out above. One among them is the following iterative procedure (Montero, 2010; Nayak & Mishra, 2012):

- 1: Define  $\varepsilon = 0.001$ , for accuracy. Initialize the weight vector,  $w_j = 1$ ;  $j = 1, 2, \dots, m$ .
- 2: Obtain  $DF_i = \sum_{j=1}^m [\partial_{ij} w_j]$ ;  $i = 1, 2, \dots, n$
- 3: Compute the coefficient of correlation,  $r(DF, \partial_j)$ , between DF and  $\partial_j$ ;  $j = 1, 2, \dots, m$
- 4: Arrange  $|r(DF, \partial_j)|$  in a descending order. This is the criterion on which the variables would enter into the DP2 formula and obtain weights.
- 5: Compute  $Z_i = \sum_{j=1}^m [\partial_{ij} w_j]$ ;  $i = 1, 2, \dots, n$ ;  $w_j = (1 - R_{j,j-1,j-2,\dots,1}^2)$  for  $j = 2, 3, \dots, m$  and  $w_1 = 1$ .
- 6: If  $\sum_{i=1}^n |DF_i - Z_i|^2 \geq \varepsilon$  then:  $DF \leftarrow Z$ , go to step-3. Otherwise: stop.

**II. The Cases when Partial Indicators are Ordinal (Ranking Scores):** When every partial indicator,  $x_j \in X$ , is ordinal (or ranking scores), then obtaining weights ( $w$ ) and the construction of ordinal composite index (synthetic indicator),  $Z$ , require a special treatment. First, transformation of  $x_{ij}$  into  $\partial_{ij}$  is neither legitimate nor required. Secondly, regression of  $x_j$  on  $x_{j-1}, x_{j-2}, \dots, x_1$  in the usual manner applicable to cardinally measured variables cannot be carried out. Thirdly,  $Z = Xw$  must be ordinal (ranking scores). Fourthly, an appropriate measure of correlation (i.e. non-parametric) has to be used since at every iteration  $r(Z, x_j)$  is computed. Fifthly, the condition of convergence would be different since any deviation of  $|DF_i - Z_i|$  would be either zero or a non-zero integer, not a small number,  $\varepsilon$ . Finally, there are several types of ranking (such as ordinal, dense, standard competition, modified competition, etc) and a choice must be made regarding the same.

**III. Objectives of the Present Work:** The present study aims at formulating a computational scheme (and developing a computer program) that may be appropriate to construct Pena's DP2 (ordinal) synthetic indicator ( $Z$ ) from the partial indicators ( $X$ ) all of which are ordinal (ranking scores). Additionally, an attempt will be made to empirically apply the method (and the computer program) to obtain the ordinal synthetic indicator.

**IV. The Computational Method:** The crux of the computational work lies in obtaining  $R_{j,j-1,\dots,1}^2$ . For this, we directly maximize the squared correlation between  $x_j$  (which is ordinal) and  $\hat{x}_{ij} = ord_i(x_{ij-1}v_{j-1} + x_{ij-2}v_{j-2} + \dots + x_{i1}v_1)$  or the expected  $x_j$ , which is also ordinal, with  $v_1, \dots, v_{j-1}$  as the decision variables (in the range  $-\gamma$  to  $\gamma$ , where  $\gamma$  could be unity). The function  $ord_i(.)$  (running over cases,  $i = 1, 2, \dots, n$ ) converts  $(.)$  into the ranking scores. For the purpose of maximization of  $R_{j,j-1,\dots,1}^2$ , we use the Differential Evolution method of global optimization, which is well known for its efficiency (Mishra, 2006).

As for computation of correlation coefficient, Karl Pearson's formula for computing correlation may be used to obtain Spearman's rank correlation coefficient. Alternatively, Kendall's tau may be used. For ranking, any one of the five possible schemes (ordinal or 1-2-3-4 rule, dense or 1-2-2-3 rule, standard competition or 1-2-2-4 rule, modified competition or 1-3-3-4 rule, fractional ranking or 1-2.5-2.5-4 rule) may be used. It may be noted, however, that the difference in ranking scores obtained by the different rules arises in case of ties only. For termination of iteration we have used  $\varepsilon = 1$ . This implies that the current  $Z$  (i.e.  $Z^{(t)}$ ) and the previous  $Z$  (i.e.  $Z^{(t-1)}$ ) are identical.

**V. The Data:** For the purpose of empirical testing of the proposed method, we have used the data from Mishra (2010), Example-1, Table-1.1. The data are on 30 items each with ranking score in 7 dimensions (i.e., 7 partial indicators). The data are reproduced here (Table-1) for a ready reference. In the table,  $Z_0$  is the composite ranking score (synthetic indicator) obtained from 7-dimensional partial indicators by applying the Ordinal Principal Component Analysis.

Table-1. Ranking Scores of Thirty individuals in Seven Dimensions and the Composite Ranking Score obtained by the Ordinal Principal Component Analysis.																	
$SL$	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	$x_6$	$x_7$	$Z_0$	$SL$	$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	$x_6$	$x_7$	$Z_0$
1	2	3	1	2	4	12	4	1	16	16	17	11	16	14	20	19	16
2	6	2	2	4	7	3	3	2	17	15	23	16	27	10	8	14	17
3	1	10	3	1	1	6	8	3	18	30	20	23	19	6	11	6	18
4	14	1	5	3	2	1	9	4	19	5	21	26	23	23	9	15	19
5	4	9	12	14	11	5	1	5	20	22	15	21	20	17	19	13	20
6	10	7	6	7	9	22	5	6	21	20	28	8	13	25	21	23	21
7	3	8	13	8	3	13	17	7	22	11	19	18	26	20	23	26	22
8	9	14	17	5	18	2	2	8	23	25	12	22	22	19	30	21	23
9	7	11	4	10	24	4	10	9	24	18	25	30	21	16	18	24	24
10	19	6	19	6	5	10	7	10	25	23	29	15	18	30	17	29	25
11	8	16	9	15	15	27	12	11	26	28	18	20	25	27	15	30	26
12	17	5	7	17	8	26	20	12	27	24	26	27	28	13	29	25	27
13	13	13	10	11	28	7	22	13	28	26	27	28	24	29	28	18	28
14	12	30	14	12	12	14	11	14	29	27	22	24	29	26	25	27	29
15	21	4	25	9	22	16	16	15	30	29	24	29	30	21	24	28	30

Source: Mishra (2010), pp. 175-77.  $Z_0$  = Composite Index by Ordinal Principal Component Analysis.

**VI. The Findings:** Presented in Table-2, all the composite ranking scores (or ordinal synthetic indicators),  $Z_{\alpha\beta}$ , are constructed by using the procedure mentioned in section-IV. The subscripts  $\alpha$  ( $\alpha=1$  for Perason/Spearman coefficient of correlation and  $\alpha=2$  for Kendall's tau) and  $\beta$  ( $\beta=0$  for 1-2-3-4 rule,  $\beta=1$  for 1-2-2-3 rule,  $\beta=2$  for 1-2-2-4 rule,  $\beta=3$  for 1-3-3-4 rule and  $\beta=4$  for 1-2.5-2.5-4 rule) specify as to the type of correlation and the rule for rank-ordering. In particular,  $Z_u$  is the un-weighted (or equally weighted) ordinal synthetic index (rank scores) obtained by  $ord_i(\sum_{j=1}^7 x_{ij})$  and  $Z_0$  is the ordinal composite index obtained by the Ordinal Principal Component Analysis. Presented in Table-3, all relative weights correspond to the synthetic indicators ( $Z_{\alpha\beta}$ ,  $Z_u$  and  $Z_0$ ) in Table-2. The relative weights sum up to unity. The last two columns of Table-3 report the appropriate ( $\alpha=1$  or 2) coefficient of correlation of  $Z_{\alpha\beta}$  with the equally weighted ordinal composite index ( $Z_u$ ) and the Ordinal Principal Component index.



**Table-4. Spearman's Correlation among Different Ordinal Composite Scores and the Partial Indicators**

$\frac{Z}{Z, x}$	$Z_{10}$	$Z_{20}$	$Z_{11}$	$Z_{21}$	$Z_{12}$	$Z_{22}$	$Z_{13}$	$Z_{23}$	$Z_{14}$	$Z_{24}$	$Z_0$	$Z_u$
$Z_{10}$	1.0000	0.9924	1.0000	0.9924	1.0000	0.9924	0.9996	0.9924	1.0000	0.9924	0.9902	0.9889
$Z_{20}$	0.9924	1.0000	0.9924	1.0000	0.9924	1.0000	0.9929	1.0000	0.9924	1.0000	0.9960	0.9969
$Z_{11}$	1.0000	0.9924	1.0000	0.9924	1.0000	0.9924	0.9996	0.9924	1.0000	0.9924	0.9902	0.9889
$Z_{21}$	0.9924	1.0000	0.9924	1.0000	0.9924	1.0000	0.9929	1.0000	0.9924	1.0000	0.9960	0.9969
$Z_{12}$	1.0000	0.9924	1.0000	0.9924	1.0000	0.9924	0.9996	0.9924	1.0000	0.9924	0.9902	0.9889
$Z_{22}$	0.9924	1.0000	0.9924	1.0000	0.9924	1.0000	0.9929	1.0000	0.9924	1.0000	0.9960	0.9969
$Z_{13}$	0.9996	0.9929	0.9996	0.9929	0.9996	0.9929	1.0000	0.9929	0.9996	0.9929	0.9915	0.9902
$Z_{23}$	0.9924	1.0000	0.9924	1.0000	0.9924	1.0000	0.9929	1.0000	0.9924	1.0000	0.9960	0.9969
$Z_{14}$	1.0000	0.9924	1.0000	0.9924	1.0000	0.9924	0.9996	0.9924	1.0000	0.9924	0.9902	0.9889
$Z_{24}$	0.9924	1.0000	0.9924	1.0000	0.9924	1.0000	0.9929	1.0000	0.9924	1.0000	0.9960	0.9969
$Z_0$	0.9902	0.9960	0.9902	0.9960	0.9902	0.9960	0.9915	0.9960	0.9902	0.9960	1.0000	0.9987
$Z_u$	0.9889	0.9969	0.9889	0.9969	0.9889	0.9969	0.9902	0.9969	0.9889	0.9969	0.9987	1.0000
$x_1$	0.8011	0.7887	0.8011	0.7887	0.8011	0.7887	0.8033	0.7887	0.8011	0.7887	0.8109	0.8082
$x_2$	0.7433	0.7811	0.7433	0.7811	0.7433	0.7811	0.7455	0.7811	0.7433	0.7811	0.7766	0.7815
$x_3$	0.7597	0.7842	0.7597	0.7842	0.7597	0.7842	0.7620	0.7842	0.7597	0.7842	0.8007	0.7980
$x_4$	0.9181	0.9012	0.9181	0.9012	0.9181	0.9012	0.9141	0.9012	0.9181	0.9012	0.8937	0.8914
$x_5$	0.6707	0.6845	0.6707	0.6845	0.6707	0.6845	0.6739	0.6845	0.6707	0.6845	0.6890	0.6934
$x_6$	0.7059	0.6770	0.7059	0.6770	0.7059	0.6770	0.7046	0.6770	0.7059	0.6770	0.6538	0.6623
$x_7$	0.8323	0.8331	0.8323	0.8331	0.8323	0.8331	0.8327	0.8331	0.8323	0.8331	0.8278	0.8194
$SAR$	5.4311	5.4498	5.4311	5.4498	5.4311	5.4498	5.4361	5.4498	5.4311	5.4498	5.4525	5.4542
$SSR$	4.2552	4.2802	4.2552	4.2802	4.2552	4.2802	4.2613	4.2802	4.2552	4.2802	4.2879	4.2862

It is interesting to note that in comparison to the Pearson/Spearman-based ( $\alpha=1$ ) composite rank scores, the Kendall's tau-based ( $\alpha=2$ ) composite rank scores have relatively weaker correlation with  $Z_u$  and  $Z_0$ .

In Table-4 we present the rank correlation (coefficients of)  $Z_{\alpha\beta}$ ,  $Z_0$  and  $Z_u$  among themselves and with the partial indicators  $x_j \in X$ ;  $j=1, 2, \dots, m$ . We also present the  $SAR$  (sum of absolute correlation,  $\sum_{j=1}^m |r(Z, x_j)|$ , for the relevant  $Z$ ) and  $SSR$  (sum of squared correlation,  $\sum_{j=1}^m |r(Z, x_j)|^2$ , for the relevant  $Z$ ). We find that the  $SAR$  as well as  $SSR$  of  $Z_0$  and  $Z_u$  are larger than those of  $Z_{\alpha\beta}$ . This implies that from the viewpoint of overall representation of the partial indicators (ranking scores) by the composite indicator (composite ranking scores),  $Z_0$  and

$Z_u$  outperform  $Z_{\alpha\beta}$  for  $\alpha$  and  $\beta$  whatsoever. Nevertheless, the weights associated with  $Z_{\alpha\beta}$  are more egalitarian.

**V. Concluding Remarks:** The findings of this study attract our attention to a number of points. First, it is computationally possible to extend the method of constructing Pena's DP2 synthetic indicators to the cases when all the partial indicators are ordinal (rank scores) and the synthetic rank scores are to be obtained from them. Secondly, in computing such synthetic rank scores, it is possible to use rank correlation (of Spearman or Kendall). It is also possible to use different schemes or rules of ranking. Thirdly, DP2-based composite ranking scores may not have better SAR and SSR than the other composite scores obtained by simple averaging or using the Ordinal Principal Component Analysis (OPCA). Fourthly, DP2-based composite scores have more egalitarian distribution of weights than the OPCA-based composite scores may have.

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## Appendix

The following FORTRAN 77 Program (ORDP2) computes the composite (synthetic) rank scores from  $m$  ( $>1$ ) given partial rank scores ( $Z[n,m]$ ),  $i=1,2, \dots, n$  and  $j=1,2, \dots, m$  each of which is a rank score obtained by the individual (case) in a particular dimension. There are  $n$  individuals.

Data is fed in an input file (filename.txt) which contains  $n$  rows (cases or individuals) in:

(a)  $m$  columns – if there is no reference index (refi) to compare. In that case the program sums the given  $m$  rank scores, orders them and ranks this total to make refi.

(b)  $m + 1$  columns – if there is an extraneous reference index, (in the last  $m+1$  column)

The program asks to choose certain parameters (regarding type of correlation, ranking rule, random number seed), and information regarding input and output files, etc which are self explanatory.

The program (codes/exe files) and the input data file must be in the same folder/directory. Output file also is stored in the same directory. The FORCE Fortran 77 compiler may be used to compile the codes. FORCE is free downloadable Fortran 77 compiler.



```

PROGRAM ORDP2
!-----
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
PARAMETER (NX=1000,MX=50, EPS=1.D0)
CHARACTER *40 INFIL,OUTFIL
INTEGER IU, IV
COMMON /RNDM/IU,IV ! RANDOM NUMBER GENERATION (IU = 4-DIGIT SEED)
COMMON /PREGRESS/YP(NX),XP(NX,MX),NCASE,MVAR,RSQ
COMMON /CORDAT/CDAT(NX,MX),QIND(NX),R(MX),NCOR
COMMON /CORLNO/ZF(NX,2)
COMMON /RANKS/NRL
DIMENSION Z(NX,MX),Y(NX),X(NX,MX),CIND(NX),ZB(MX),SD(MX),RZ(MX)
DIMENSION ZMIN(MX),ZMAX(MX),DF(NX),DFF(NX),YH(NX),IR(MX),W(MX)
DIMENSION REFI(NX),DFZ(NX)
! REFI IS THE REFERENCE INDEX, IF ANY. IF THERE IS NONE, THEN THIS
! PROGRAM GENERATES IT AS RANK SCORE OF TOTAL PARTIAL RANKS-SCORES
!=====
WRITE(*,*)'===== DP2 SYNTHETIC INDICES OF RANK DATA ====='
WRITE(*,*)'---ALGORITHM AND PROGRAM BY PROF.SK MISHRA (NEHU) ====='
WRITE(*,*)
WRITE(*,*)'NO. OF CASES AND VARIABLES ?'
READ(*,*) N,M
NCASE=N
MVAR=M
WRITE(*,*)'CORRELATION TYPE ?'
WRITE(*,*)'CORRELATION : PEARSON/SPEARMAN RHO (1), KENDALL TAU(2)'
READ(*,*) NCOR
C  NRL=0 FOR ORDINAL RANKING (1-2-3-4 RULE);
C  NRL=1 FOR DENSE RANKING (1-2-2-3 RULE);
C  NRL=2 FOR STANDARD COMPETITION RANKING (1-2-2-4 RULE);
C  NRL=3 FOR MODIFIED COMPETITION RANKING (1-3-3-4 RULE);
C  NRL=4 FOR FRACTIONAL RANKING (1-2.5-2.5-4 RULE);
WRITE(*,*)'WHAT WILL BE THE RANKING RULE ?'
WRITE(*,*)'NRL =0 (1,2,3,4); NRL=1 (1,2,2,3); NRL=2 (1,2,2,4)'
WRITE(*,*)'NRL =3 (1,3,3,4); NRL=4 (1,2.5,2.5,4)'
READ(*,*) NRL

WRITE(*,*)'A FOUR-DIGIT POSITIVE ODD INTEGER, SAY, 1171'
READ(*,*) IU
WRITE(*,*)'INPUT AND OUTPUT FILES ?'
READ(*,*) INFIL,OUTFIL
!=====
WRITE(*,*)'DOES THE DATA SET HAVE THE REFERENCE COMPOSITE INDEX?'
WRITE(*,*)'IF NO, FEED 0 ELSE FEED ANY NON-ZERO NUMBER'
READ(*,*) IREFI
OPEN(7, FILE=INFIL)
DO I=1,N
IF(IREFI.EQ.0) THEN
READ(7,*)(Z(I,J),J=1,M)
ELSE
READ(7,*)(Z(I,J),J=1,M),REFI(I)
ENDIF
ENDDO
CLOSE(7)

IF(IREFI.EQ.0) THEN ! GENERATE REFI FROM M GIVEN RANK SCORES

```

```

DO I=1,N
REFI(I)=0
DO J=1,M
REFI(I)=REFI(I)+Z(I,J)
ENDDO
ENDDO
CALL DORANK(REFI,N) ! RANKING OF REFI
ENDIF

```

```

DO I=1,N
WRITE(*,3)I,(Z(I,J),J=1,M),REFI(I)
ENDDO

```

```

3 FORMAT(I4,20F4.0)
WRITE(*,*)
WRITE(*,*)'=====
WRITE(*,*)
! FIND MEAN AND STANDARD DEVIATION OF ALL VARIABLES
DO J=1,M
ZB(J)=0.D0
SD(J)=0.D0
DO I=1,N
ZB(J)=ZB(J)+Z(I,J)
SD(J)=SD(J)+Z(I,J)**2
ENDDO
SD(J)=DSQRT((N*SD(J)-ZB(J)**2))/N
ZB(J)=ZB(J)/N
ENDDO
WRITE(*,*)'MEAN =',(ZB(J),J=1,M)
WRITE(*,*)'SD =',(SD(J),J=1,M)
! FIND MINIMUM AND MAXIMUM OF EACH VARIABLE
DO J=1,M
ZMIN(J)=Z(1,J)
ZMAX(J)=Z(1,J)
DO I=2,N
IF(ZMIN(J).GT.Z(I,J)) ZMIN(J)=Z(I,J)
IF(ZMAX(J).LT.Z(I,J)) ZMAX(J)=Z(I,J)
ENDDO
ENDDO
! STANDARDIZATION OF VARIABLES
!DO J=1,M
!DO I=1,N
!Z(I,J)=(Z(I,J)-ZMIN(J))/SD(J)
! Z(I,J)=(Z(I,J)-ZMIN(J))/(ZMAX(J)-ZMIN(J))
!ENDDO
!ENDDO
OPEN(8,FILE='ZDAT.TXT')
DO I=1,N
WRITE(8,2)(Z(I,J),J=1,M)
ENDDO
CLOSE(8)
2 FORMAT(10F8.5)
! PAUSE
! MAKE THE INITIAL COMPOSITE INDEX (DF)

```

```

DO I=1,N
DF(I)=0.D0
DO J=1,M
DF(I)=DF(I)+Z(I,J)
ENDDO
ENDDO
!-----
CALL DORANK(DF,N) ! RANKING OF DF
!-----
DO I=1,N
DFZ(I)=DF(I) ! PRESERVE THE INITIAL DF
ENDDO

! -----
! FIND CORRELATION BETWEEN DF AND THE CONSTITUENT VARIABLES (Z)
ITERATION=0
DELTA=1.0D30
DO WHILE (DELTA.GT.EPS) ! DO WHILE LOOP BEGINS
ITERATION=ITERATION+1

WRITE(*,*)
WRITE(*,*)'***** ITERATION',ITERATION,'*****'
*****'

WRITE(*,*)
DO J=1,M
DO I=1,N
ZF(I,1)=Z(I,J)
ZF(I,2)=DF(I)
ENDDO

IF(NCOR.EQ.1) CALL CORLN(RHO)
IF(NCOR.EQ.2) CALL TAU(RHO)

RZ(J)=DABS(RHO)
IR(J)=J ! INDEX OF RZ
ENDDO
WRITE(*,*)'CORRELATIONS WITH SYNTHETIC INDEX'
WRITE(*,*) (' ',IR(J),' ',RZ(J),J=1,M)
! PAUSE
! ORDER THE VARIABLES ACCORDING TO MAGNITUDE OF RZ(J) THAT IS, R
DO J=1,M-1
DO JJ=J+1,M
IF(RZ(J).LT.RZ(JJ)) THEN
T=RZ(J)
RZ(J)=RZ(JJ)
RZ(JJ)=T
IT=IR(J)
IR(J)=IR(JJ)
IR(JJ)=IT
ENDIF
ENDDO
ENDDO
WRITE(*,*)'ORDERED CORRELATIONS WITH SYNTHETIC INDEX'
WRITE(*,*) (' ',IR(J),' ',RZ(J),J=1,M)
!PAUSE
! COMPUTATION OF WEIGHTS

```

```

W(1)=1.D0
DO J=2,M
! MAKE Y
DO I=1,N
YP(I)=Z(I,IR(J))
ENDDO
! MAKE X
DO JJ=1,J-1
DO I=1,N
XP(I,JJ)=Z(I,IR(JJ))
ENDDO
ENDDO

MVAR=J
DO I=1,N
XP(I,MVAR)=1.D0
ENDDO
NCASE=N
!-----
CALL DE(RSQUARE) ! DIFFERENTIAL EVOLUTION OPTIMIZER
!-----
WRITE(*,*)'RSQUARE =', RSQUARE
W(J)=1.D0-RSQUARE
ENDDO
! WITH THIS WEIGHT MAKE NEW DF
DO I=1,N
DFF(I)=0.D0
DO J=1,M
DFF(I)=DFF(I)+Z(I,IR(J))*W(J)
ENDDO
ENDDO
!-----
CALL DORANK(DFF,N) ! RANKING OF DFF
!-----
! FIND THE DISTANCE BETWEEN DFF AND DF
DELTA=0.D0
DO I=1,N
DELTA=DELTA+ DABS(DF(I)-DFF(I))**2
ENDDO
WRITE(*,*)'DELTA =',DELTA
! READ(*,*) IGO

DO I=1,N
DF(I)=DFF(I)
ENDDO
WRITE(*,*)'WEIGHTS=',(W(J),J=1,M)
ENDDO ! DO WHILE LOOP ENDS
!-----
DO J=1,M-1
DO JJ=J+1,M
IF(IR(J).GT.IR(JJ)) THEN
T=W(J)
W(J)=W(JJ)
W(JJ)=T
IT=IR(J)
IR(J)=IR(JJ)

```

```

IR(JJ)=IT
ENDIF
ENDDO
ENDDO

```

```

OPEN(7,FILE=OUTFIL)
WRITE(*,*)'.....'
WRITE(7,*)'.....'

```

```

WRITE(*,*)'SERIALIZED WEIGHTS ARE AS FOLLOWS='
WRITE(*,*)(W(J),J=1,M)
WRITE(7,*)'SERIALIZED WEIGHTS ARE AS FOLLOWS='
WRITE(7,*)(W(J),J=1,M)
SW=0.D0
DO J=1,M
SW=SW+W(J)
ENDDO
WRITE(*,*)'RELATIVE WEIGHTS =',(W(J)/SW,J=1,M)
WRITE(7,*)'RELATIVE WEIGHTS =',(W(J)/SW,J=1,M)
DO I=1,N
CIND(I)=DFF(I) ! THE PENA-DP2 INDEX
ENDDO

```

```

DO J=1,M
DO I=1,N
ZF(I,1)=CIND(I)
ZF(I,2)=Z(I,J)
ENDDO
IF(NCOR.EQ.1) CALL CORLN(RHO)
IF(NCOR.EQ.2) CALL TAU(RHO)
RZ(J)=RHO
ENDDO

```

```

WRITE(*,*)'RHO(Z,X) =',(RZ(J),J=1,M)
WRITE(7,*)'RHO(Z,X) =',(RZ(J),J=1,M)
SAR=0.D0
SSR=0.D0
DO J=1,M
SAR=SAR+DABS(RZ(J))
SSR=SSR+RZ(J)**2
ENDDO

```

```

DO I=1,N
X(I,1)=CIND(I)
X(I,2)=REFI(I)
DO J=3,M+2
X(I,J)=Z(I,J-2)
ENDDO
ENDDO
!CALL STANDARD(X,N,M+2)
WRITE(*,*) 'COMPOSITE SCORES AND PARTIAL SCORES'
WRITE(7,*) 'COMPOSITE SCORES AND PARTIAL SCORES'
DO I=1,N
WRITE(7,1) (X(I,J),J=1,M+2)

```

```

ENDDO
WRITE(*,*)'NOTE:(1). COMPUTED COMPOSITE SCORES; (2). REF COMPOSITE
* SCORES,'
WRITE(7,*)'NOTE:(1). COMPUTED COMPOSITE SCORES; (2). REF COMPOSITE
* SCORES,'
WRITE(*,*)'(3, 4, ...). PARTIAL RANK SCORES'
WRITE(7,*)'(3, 4, ...). PARTIAL RANK SCORES'

```

```
1 FORMAT(20F4.0)
```

```

DO I=1,N
ZF(I,1)=DFZ(I)
ZF(I,2)=CIND(I)
ENDDO
IF(NCOR.EQ.1) CALL CORLN(R1)
IF(NCOR.EQ.2) CALL TAU(R1)

```

```

DO I=1,N
ZF(I,1)=CIND(I)
ZF(I,2)=REFI(I)
ENDDO

```

```

IF(NCOR.EQ.1) CALL CORLN(R2)
IF(NCOR.EQ.2) CALL TAU(R2)
WRITE(*,*)'SUM OF ABS CORRELATION & SQUARED CORRELATION',SAR,SSR
WRITE(7,*)'SUM OF ABS CORRELATION & SQUARED CORRELATION',SAR,SSR

```

```

WRITE(*,*)'CORRELATION BETWEEN (DP2,DF) & (DP2,REFI)',R1,R2
WRITE(7,*)'CORRELATION BETWEEN (DP2,DF) & (DP2,REFI)',R1,R2
WRITE(*,*)'REFI IS ANY GIVEN EXTRENEOUS COMPOSITE INDEX, OR'
WRITE(7,*)'REFI IS ANY GIVEN EXTRENEOUS COMPOSITE INDEX, OR'
WRITE(*,*)'REFI IS THE RANK SCORE OF THE TOTAL OF PARTIAL SCORES'
WRITE(7,*)'REFI IS THE RANK SCORE OF THE TOTAL OF PARTIAL SCORES'

```

```

CLOSE(7)
WRITE(*,*)'OVER'
PAUSE
END

```

```
C -----
```

```
SUBROUTINE DE(RSQUARE)
```

```

C PROGRAM: "DIFFERENTIAL EVOLUTION ALGORITHM" OF GLOBAL OPTIMIZATION
C THIS METHOD WAS PROPOSED BY R. STORN AND K. PRICE IN 1995. REF --
C "DIFFERENTIAL EVOLUTION - A SIMPLE AND EFFICIENT ADAPTIVE SCHEME
C FOR GLOBAL OPTIMIZATION OVER CONTINUOUS SPACES" : TECHNICAL REPORT
C INTERNATIONAL COMPUTER SCIENCE INSTITUTE, BERKLEY, 1995.
C PROGRAM BY SK MISHRA, DEPT. OF ECONOMICS, NEHU, SHILLONG (INDIA)
C -----

```

```
C PROGRAM DE
```

```

IMPLICIT DOUBLE PRECISION (A-H, O-Z) ! TYPE DECLARATION
PARAMETER(NMAX=500,MMAX=50) ! MAXIMUM DIMENSION PARAMETERS
PARAMETER(NX=1000,MX=50)
PARAMETER (RX1=0.D0, RX2=0.D0) ! TO BE ADJUSTED SUITABLY, IF NEEDED

```

```

C RX1 AND RX2 CONTROL THE SCHEME OF CROSSOVER. (0 <= RX1 <= RX2) <=1
C RX1 DETERMINES THE UPPER LIMIT OF SCHEME 1 (AND LOWER LIMIT OF
C SCHEME 2; RX2 IS THE UPPER LIMIT OF SCHEME 2 AND LOWER LIMIT OF

```

```

C  SCHEME 3. THUS RX1 = .2 AND RX2 = .8 MEANS 0-20% SCHEME1, 20 TO 80
C  PERCENT SCHEME 2 AND THE REST (80 TO 100 %) SCHEME 3.
C  PARAMETER(NCROSS=2) ! CROSS-OVER SCHEME (NCROSS <=0 OR =1 OR =>2)
C  PARAMETER(IPRINT=100,EPS=1.D-08)!FOR WATCHING INTERMEDIATE RESULTS
C  IT PRINTS THE INTERMEDIATE RESULTS AFTER EACH IPRINT ITERATION AND
C  EPS DETERMINES ACCURACY FOR TERMINATION. IF EPS= 0, ALL ITERATIONS
C  WOULD BE UNDERGONE EVEN IF NO IMPROVEMENT IN RESULTS IS THERE.
C  ULTIMATELY "DID NOT CONVERGE" IS REOPORTED.
COMMON /RNDM/IU,IV ! RANDOM NUMBER GENERATION (IU = 4-DIGIT SEED)
COMMON /KFF/NFCALL,FTIT ! FUNCTION CODE, NO. OF CALLS * TITLE
COMMON /XBASE/XBAS
COMMON /PREGRESS/YP(NX),XP(NX,MX),NCASE,MVAR,RSQ
INTEGER IU,IV  ! FOR RANDOM NUMBER GENERATION
CHARACTER *70 FTIT ! TITLE OF THE FUNCTION
C  -----
C  THE PROGRAM REQUIRES INPUTS FROM THE USER ON THE FOLLOWING -----
C  (1) NO. OF VARIABLES IN THE FUNCTION (M);
C  (2) N=POPULATION SIZE (SUGGESTED 10 TIMES OF NO. OF VARIABLES, M,
C  FOR SMALLER PROBLEMS N=100 WORKS VERY WELL);
C  (3) PCROS = PROB. OF CROSS-OVER (SUGGESTED : ABOUT 0.85 TO .99);
C  (4) FACT = SCALE (SUGGESTED 0.5 TO .95 OR 1, ETC);
C  (5) ITER = MAXIMUM NUMBER OF ITERATIONS PERMITTED (5000 OR MORE)
C  (6) RANDOM NUMBER SEED (4 DIGITS INTEGER)
C  -----
C  DIMENSION X(NMAX,MMAX),Y(NMAX,MMAX),A(MMAX),FV(NMAX)
C  DIMENSION IR(3),XBAS(1000,50)
C  -----
C  ----- SELECT THE FUNCTION TO MINIMIZE AND ITS DIMENSION -----
C  FTIT='CONSTRUCTION OF INDEX FROM M VARIABLES '
C  SPECIFY OTHER PARAMETERS -----
C  !WRITE(*,*)'POPULATION SIZE [N] AND NO. OF ITERATIONS [ITER] ?'
C  !WRITE(*,*)'SUGGESTED : N => 100 OR =>10.M; ITER 10000 OR SO'
C  !READ(*,*) N,ITER
C  M=MVAR
C  N=100
C  ITER=100000
C  !WRITE(*,*)'CROSSOVER PROBABILITY [PCROS] AND SCALE [FACT] ?'
C  !WRITE(*,*)'SUGGESTED : PCROS ABOUT 0.9; FACT=.5 OR LARGER BUT <=1'
C  !READ(*,*) PCROS,FACT
C  PCROSS=0.9
C  FACT=0.5
C  !WRITE(*,*)'RANDOM NUMBER SEED ?'
C  !WRITE(*,*)'A FOUR-DIGIT POSITIVE ODD INTEGER, SAY, 1171'
C  !READ(*,*) IU
C  NFCALL=0 ! INITIALIZE COUNTER FOR FUNCTION CALLS
C  GBEST=1.D30 ! TO BE USED FOR TERMINATION CRITERION
C  INITIALIZATION : GENERATE X(N,M) RANDOMLY
C  DO I=1,N
C  DO J=1,M
C  CALL RANDOM(RAND) ! GENERATES INITION X WITHIN
C  X(I,J)=(RAND-.5D00)*100 ! GENERATES INITION X WITHIN
C  RANDOM NUMBERS BETWEEN -RRANGE AND +RRANGE (BOTH EXCLUSIVE)
C  CALL RANDOM(RAND)
C  XBAS(I,J)=(RAND-0.5)
C  X(I,J)=XBAS(I,J)! TAKES THESE NUMBERS FROM THE MAIN PROGRAM
C  ENDDO

```

```

!WRITE(*,*)(X(I,J),J=1,MVAR),'GENERATED DECISION VARIABLES'
ENDDO
WRITE(*,*)'=====
IPCOUNT=0
DO 100 ITR=1,ITER ! ITERATION BEGINS
C -----
C  EVALUATE ALL X FOR THE GIVEN FUNCTION
DO I=1,N
DO J=1,M
A(J)=X(I,J)
ENDDO
CALL FUNC(A,M,F)
C  STORE FUNCTION VALUES IN FV VECTOR
FV(I)=F
ENDDO

C -----
C  FIND THE FITTEST (BEST) INDIVIDUAL AT THIS ITERATION
    FBEST=FV(1)
    KB=1
    DO IB=2,N
        IF(FV(IB).LT.FBEST) THEN
            FBEST=FV(IB)
            KB=IB
        ENDIF
    ENDDO
C  BEST FITNESS VALUE = FBEST : INDIVIDUAL X(KB)
C -----
C  GENERATE OFFSPRINGS
DO I=1,N ! I LOOP BEGINS
C  INITIALIZE CHILDREN IDENTICAL TO PARENTS; THEY WILL CHANGE LATER
    DO J=1,M
        Y(I,J)=X(I,J)
    ENDDO
C  SELECT RANDOMLY THREE OTHER INDIVIDUALS
20  DO IRI=1,3 ! IRI LOOP BEGINS
    IR(IRI)=0

    CALL RANDOM(RAND)
    IRJ=INT(RAND*N)+1
C  CHECK THAT THESE THREE INDIVIDUALS ARE DISTICT AND OTHER THAN I
    IF(IRI.EQ.1.AND.IRJ.NE.I) THEN
        IR(IRI)=IRJ
    ENDIF
    IF(IRI.EQ.2.AND.IRJ.NE.I.AND.IRJ.NE.IR(1)) THEN
        IR(IRI)=IRJ
    ENDIF
    IF(IRI.EQ.3.AND.IRJ.NE.I.AND.IRJ.NE.IR(1).AND.IRJ.NE.IR(2)) THEN
        IR(IRI)=IRJ
    ENDIF
    ENDDO ! IRI LOOP ENDS
C  CHECK IF ALL THE THREE IR ARE POSITIVE (INTEGERS)
DO IX=1,3
    IF(IR(IX).LE.0) THEN
        GOTO 20 ! IF NOT THEN REGENERATE
    ENDIF

```



```

      ENDDO
C   THREE RANDOMLY CHOSEN INDIVIDUALS DIFFERENT FROM I AND DIFFERENT
C   FROM EACH OTHER ARE IR(1),IR(2) AND IR(3)
C   ===== RANDOMIZATION OF NCROSS =====
C   RANDOMIZES NCROSS
      NCROSS=0
      CALL RANDOM(RAND)
      IF(RAND.GT.RX1) NCROSS=1 ! IF RX1=>1, SCHEME 2 NEVER IMPLEMENTED
      IF(RAND.GT.RX2) NCROSS=2 ! IF RX2=>1, SCHEME 3 NEVER IMPLEMENTED

C   ----- SCHEME 1 -----
C   NO CROSS OVER, ONLY REPLACEMENT THAT IS PROBABILISTIC
      IF(NCROSS.LE.0) THEN
        DO J=1,M    ! J LOOP BEGINS
          CALL RANDOM(RAND)
          IF(RAND.LE.PCROSS) THEN ! REPLACE IF RAND < PCROS
            A(J)=X(IR(1),J)+(X(IR(2),J)-X(IR(3),J))*FACT ! CANDIDATE CHILD
          ENDIF
        ENDDO ! J LOOP ENDS
      ENDIF

C   ----- SCHEME 2 -----
C   THE STANDARD CROSSOVER SCHEME
C   CROSSOVER SCHEME (EXPONENTIAL) SUGGESTED BY KENNETH PRICE IN HIS
C   PERSONAL LETTER TO THE AUTHOR (DATED SEPTEMBER 29, 2006)
      IF(NCROSS.EQ.1) THEN
        CALL RANDOM(RAND)
        JR=INT(RAND*M)+1
        J=JR
        2  A(J)=X(IR(1),J)+FACT*(X(IR(2),J)-X(IR(3),J))
          J=J+1
          IF(J.GT.M) J=1
          IF(J.EQ.JR) GOTO 10
          CALL RANDOM(RAND)
          IF(PCROS.LE.RAND) GOTO 2
        6  A(J)=X(I,J)
          J=J+1
          IF(J.GT.M) J=1
          IF (J.EQ.JR) GOTO 10
          GOTO 6
        10 CONTINUE
      ENDIF

C   ----- SCHEME 3 -----
C   ESPECIALLY SUITABLE TO NON-DECOMPOSABLE (NON-SEPERABLE) FUNCTIONS
C   CROSSOVER SCHEME (NEW) SUGGESTED BY KENNETH PRICE IN HIS
C   PERSONAL LETTER TO THE AUTHOR (DATED OCTOBER 18, 2006)
      IF(NCROSS.GE.2) THEN
        CALL RANDOM(RAND)
        IF(RAND.LE.PCROS) THEN
          CALL NORMAL(RN)
          DO J=1,M
            A(J)=X(I,J)+(X(IR(1),J)+ X(IR(2),J)-2*X(I,J))*RN
          ENDDO
        ELSE
          DO J=1,M
            A(J)=X(I,J)+(X(IR(1),J)- X(IR(2),J))*FACT ! FACT ASSUMED TO BE 1
          ENDDO
        ENDIF
      ENDIF

```

```

      ENDIF
ENDIF
C -----
  CALL FUNC(A,M,F) ! EVALUATE THE OFFSPRING
  IF(F.LT.FV(I)) THEN ! IF BETTER, REPLACE PARENTS BY THE CHILD
    FV(I)=F
    DO J=1,M
      Y(I,J)=A(J)
    ENDDO
  ENDIF
ENDDO ! I LOOP ENDS
DO I=1,N
DO J=1,M
X(I,J)=Y(I,J) ! NEW GENERATION IS A MIX OF BETTER PARENTS AND
C      BETTER CHILDREN
ENDDO
ENDDO
IPCOUNT=IPCOUNT+1
IF(IPCOUNT.EQ.IPRINT) THEN
DO J=1,M
A(J)=X(KB,J)
ENDDO
WRITE(*,*)(X(KB,J),J=1,M),' FBEST UPTO NOW = ',FBEST
WRITE(*,*)'TOTAL NUMBER OF FUNCTION CALLS = ',NFCALL
  IF(DABS(FBEST-GBEST).LT.EPS) THEN
!   WRITE(*,*) FTIT
    WRITE(*,*)'CONVERGED!'
    GOTO 999
  ELSE
    GBEST=FBEST
  ENDIF
IPCOUNT=0
ENDIF
C -----
100 ENDDO ! ITERATION ENDS : GO FOR NEXT ITERATION, IF APPLICABLE
C -----
!WRITE(*,*)'DID NOT CONVERGE. REDUCE EPS OR RAISE ITER OR DO BOTH'
!WRITE(*,*)'INCREASE N, PCROS, OR SCALE FACTOR (FACT)'

999 RSQ=FBEST
RSQUARE=-RSQ
RETURN
END
C -----
SUBROUTINE NORMAL(R)
C PROGRAM TO GENERATE N(0,1) FROM RECTANGULAR RANDOM NUMBERS
C IT USES BOX-MULLER VARIATE TRANSFORMATION FOR THIS PURPOSE.
C -----
C ----- BOX-MULLER METHOD BY GEP BOX AND ME MULLER (1958) -----
C BOX, G. E. P. AND MULLER, M. E. "A NOTE ON THE GENERATION OF
C RANDOM NORMAL DEVIATES." ANN. MATH. STAT. 29, 610-611, 1958.
C IF U1 AND U2 ARE UNIFORMLY DISTRIBUTED RANDOM NUMBERS (0,1),
C THEN X=[(-2*LN(U1))**.5]*(COS(2*PI*U2) IS N(0,1)
C ALSO, X=[(-2*LN(U1))**.5]*(SIN(2*PI*U2) IS N(0,1)
C PI = 4*ARCTAN(1.0)= 3.1415926535897932384626433832795
C 2*PI = 6.283185307179586476925286766559

```

```

C -----
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON /RNDM/IU,IV
INTEGER IU,IV
C -----
CALL RANDOM(RAND) ! INVOKES RANDOM TO GENERATE UNIFORM RAND [0, 1]
U1=RAND ! U1 IS UNIFORMLY DISTRIBUTED [0, 1]
CALL RANDOM(RAND) ! INVOKES RANDOM TO GENERATE UNIFORM RAND [0, 1]
U2=RAND ! U1 IS UNIFORMLY DISTRIBUTED [0, 1]
R=DSQRT(-2.D0*DLOG(U1))
R=R*DCOS(U2*6.283185307179586476925286766559D00)
C  R=R*DCOS(U2*6.28318530718D00)
RETURN
END
C -----
C  RANDOM NUMBER GENERATOR (UNIFORM BETWEEN 0 AND 1 - BOTH EXCLUSIVE)
SUBROUTINE RANDOM(RAND1)
DOUBLE PRECISION RAND1
COMMON /RNDM/IU,IV
INTEGER IU,IV
IV=IU*65539
IF(IV.LT.0) THEN
IV=IV+2147483647+1
ENDIF
RAND=IV
IU=IV
RAND=RAND*0.4656613E-09
RAND1= DBLE(RAND)
RETURN
END
C -----
SUBROUTINE FUNC(X,M,F)
PARAMETER (NX=1000,MX=50)
C  TEST FUNCTIONS FOR GLOBAL OPTIMIZATION PROGRAM
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON /RNDM/IU,IV
COMMON /PREGRESS/YP(NX),XP(NX,MX),NCASE,MVAR,RSQ
COMMON /KFF/NFCALL,FTIT
INTEGER IU,IV
DIMENSION X(*)
CHARACTER *70 FTIT
NFCALL=NFCALL+1 ! INCREMENT TO NUMBER OF FUNCTION CALLS
C -----
!WRITE(*,*)(X(I),I=1,MVAR),' FUNC DE DECISION VARIABLES'
CALL CORDINATE(M,X,F)
RETURN
END
C -----
SUBROUTINE CORDINATE(M,X,F)
!PARAMETER (MVAR=6)! CHANGE THE PARAMETERS HERE AS NEEDED.
PARAMETER(NX=1000,MX=50)
C -----
C  NOB=NO. OF OBSERVATIONS (CASES) & MVAR= NO. OF VARIABLES
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON /RNDM/IU,IV
COMMON /CORDAT/CDAT(NX,MX),QIND(NX),R(MX),NCOR

```

```

COMMON /GETRANK/MRANK
COMMON /PREGRESS/YP(NX),XP(NX,MX),NCASE,MVAR,RSQ
COMMON /CORLNO/ZF(NX,2)
INTEGER IU,IV
DIMENSION X(*)
!WRITE(*,*)(X(I),I=1,MVAR),' DE DECISION VARIABLES'
DO I=1,MVAR
IF(X(I).LT.-1.0D0.OR.X(I).GT.1.0D0) THEN
CALL RANDOM(RAND)
X(I)=(RAND-0.5D0)*2
ENDIF

ENDDO
DO I=1,NCASE
!WRITE(*,*)'XP ='',(XP(I,J),J=1,MVAR)
ENDDO

C  CONSTRUCT EXPECTED VARIABLE
DO I=1,NCASE
QIND(I)=0.D0
DO J=1,MVAR
QIND(I)=QIND(I)+XP(I,J)*X(J)
ENDDO
!WRITE(*,*)I,QIND(I),' QIND'
ENDDO

C  -----
!FIND THE RANK OF QIND
CALL DORANK(QIND,NCASE)

C  -----
C  COMPUTE CORRELATIONS
DO I=1,NCASE
ZF(I,1)=QIND(I)
ZF(I,2)=YP(I)
ENDDO
DO I=1,NCASE
!WRITE(*,*)I, ZF(I,1),ZF(I,2),' : Z1 AND Z2 BEFORE CORLN CALLED'
ENDDO

IF(NCOR.EQ.1) CALL CORLN(RHO)
IF(NCOR.EQ.2) CALL TAU(RHO)

!-----
F=-DABS(RHO)**2
RETURN
END

C  -----
SUBROUTINE CORLN(RHO)
PARAMETER (NX=1000, MX=50)
C  NOB = NO. OF CASES
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON /PREGRESS/YP(NX),XP(NX,MX),NCASE,MVAR,RSQ
COMMON /CORLNO/ZF(NX,2)
DIMENSION AV(2),SD(2)
NOB=NCASE
DO I=1,NOB
!WRITE(*,*)I,ZF(I,1),ZF(I,2), 'IT IS IN CORRELATION PROGRAM'

```

```

ENDDO
DO J=1,2
AV(J)=0.D0
SD(J)=0.D0
DO I=1,NOB
AV(J)=AV(J)+ZF(I,J)
SD(J)=SD(J)+ZF(I,J)**2
ENDDO
ENDDO
DO J=1,2
AV(J)=AV(J)/NOB
SD(J)=DSQRT(SD(J)/NOB-AV(J)**2)
ENDDO
C  WRITE(*,*)'AV AND SD ', AV(1),AV(2),SD(1),SD(2)
RHO=0.D0
DO I=1,NOB
RHO=RHO+(ZF(I,1)-AV(1))*(ZF(I,2)-AV(2))
ENDDO
RHO=(RHO/NOB)/(SD(1)*SD(2))
! WRITE(*,*)'RHO =' ,RHO
! PAUSE
RETURN
END

C  -----
SUBROUTINE TAU(RHO)
PARAMETER (NX=1000, MX=50)
C  NOB = NO. OF CASES
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON /PREGRESS/YP(NX),XP(NX,MX),NCASE,MVAR,RSQ
COMMON /CORLNO/ZF(NX,2)
RHO=0.D0
DO I=1,NCASE
DO J=1,NCASE
IF((ZF(I,1).GT.ZF(J,1)).AND.(ZF(I,2).GT.ZF(J,2))) RHO=RHO+1.D0
ENDDO
ENDDO
RHO=4.D0*RHO/(NCASE**2-NCASE)-1.D0
! WRITE(*,*)'RHO =' ,RHO
! PAUSE
RETURN
END

C  -----
SUBROUTINE DORANK(X,N)! N IS THE NUMBER OF OBSERVATIONS
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C  !THIS PROGRAM RETURNS RANK-ORDER OF A GIVEN VECTOR
PARAMETER (MXD=1000)! MXD IS MAX DIMENSION FOR TEMPORARY VARIABLES
PARAMETER (NX=1000)
! THAT ARE LOCAL AND DO NOT GO TO THE INVOKING PROGRAM
! X IS THE VARIABLE TO BE SUBSTITUTED BY ITS RANK VALUES
COMMON /RANKS/NRL
! THIS VALUE IS TO BE SET BY THE USER
C      !THE VALUE OF NRL DECIDES THE SCHEME OF RANKINGS
C
C  NRULE=0 FOR ORDINAL RANKING (1-2-3-4 RULE);
C  NRULE=1 FOR DENSE RANKING (1-2-2-3 RULE);
C  NRULE=2 FOR STANDARD COMPETITION RANKING (1-2-2-4 RULE);

```

```

C  NRULE=3 FOR MODIFIED COMPETITION RANKING (1-3-3-4 RULE);
C  NRULE=4 FOR FRACTIONAL RANKING (1-2.5-2.5-4 RULE);
  DIMENSION X(NX),NF(MXD),NCF(MXD),RANK(MXD),ID(MXD),XX(MXD)
C  GENERATE ID(I),I=1,N
  DO I=1,N
    ID(I)=I
    NF(I)=0
  ENDDO
C  ARRANGE DATA (X) AND THE IDS IN ASCENDING ORDER
  DO I=1,N-1
    DO II=I,N
      IF(X(II).LT.X(I)) THEN
        TEMP=X(I)
        X(I)=X(II)
        X(II)=TEMP
        ITEMP=ID(I)
        ID(I)=ID(II)
        ID(II)=ITEMP
      ENDIF
    ENDDO
  ENDDO
C  MAKE DISCRETE UNGROUPED FREQUENCY TABLE
  K=0
  J=1
1  K=K+1
  XX(K)=X(J)
  NF(K)=0
  DO I=J,N
    IF(XX(K).EQ.X(I)) THEN
      NF(K)=NF(K)+1
    ELSE
      J=I
    ENDIF
  ENDDO
2  KK=K
  DO K=1,KK
    IF(K.EQ.1) THEN
      NCF(K)=NF(K)
    ELSE
      NCF(K)=NCF(K-1)+NF(K)
    ENDIF
  ENDDO
  DO I=1,N
    RANK(I)=1.D0
  ENDDO

  IF(NRL.GT.4) THEN
    WRITE(*,*)'RANKING RULE CODE GREATER THAN 4 NOT PERMITTED',NRL
    STOP
  ENDIF

```

```

IF(NRL.LT.0) THEN
WRITE(*,*)'RANKING RULE CODE LESS THAN 0 NOT PERMITTED',NRL
STOP
ENDIF

```

```

IF(NRL.EQ.0) THEN
DO I=1,N
RANK(I)=I
ENDDO
ENDIF

```

```

C -----
IF(NRL.GT.0) THEN
DO K=1,KK
IF(K.EQ.1) THEN
K1=1
ELSE
K1=NCF(K-1)+1
ENDIF
K2=NCF(K)
DO I=K1,K2
SUM=0.D0
DO II=K1,K2
SUM=SUM+II
ENDDO
KX=(K2-K1+1)
IF(NRL.EQ.1)RANK(I)=K ! DENSE RANKING (1-2-2-3 RULE)
IF(NRL.EQ.2)RANK(I)=K1!STANDARD COMPETITION RANKING(1-2-2-4 RULE)
IF(NRL.EQ.3)RANK(I)=K2!MODIFIED COMPETITION RANKING(1-3-3-4 RULE)
IF(NRL.EQ.4)RANK(I)=SUM/KX !FRACTIONAL RANKING (1-2.5-2.5-4 RULE)
ENDDO
ENDDO
ENDIF

```

```

C -----
DO I=1,N
X(ID(I))=RANK(I) ! BRINGS THE DATA TO ORIGINAL SEQUENCE
ENDDO
RETURN
END

```